BODY TEMPERATURE AND BASAL METABOLIC CHANGES DURING ACCLIMATIZATION TO ALTITUDE (3,500 m) IN MAN

LAZAR MATHEW, S.S. PURKAYASTHA, J. SEN GUPTA AND M.S. MALHOTRA

Defence Institute of Physiology and Allied Sciences, Delhi Cantt, New Delhi-110010

Summary: Oral temperature ($\overline{T}_{or}$), mean weighted skin temperature ($\overline{T}_s$), mean body temperature ($\overline{T}_b$) and basal exygen consumption were studied on twelve young men at sea level. Then they were flown to an altitude of 3,500 m and the readings were continued after 24 hours of their arrival and thereafter at four day intervals for a period of 25 days. Thereafter the subjects were flown back and retested at sea level. Oxygen consumption was recorded at weekly intervals only. The changes in body temperature were compared with those of their basal oxygen consumption. The results indicate that there is a slight rise in the T_{or} on arrival at altitude and thereafter a gradual fall. A steady and continuous fall was recorded in T_s and T_b throughout the stay at altitude. The basal oxygen consumption showed an initial rise which has come back to normal by the third week of their stay at altitude. On retest, the valves of body temperature and oxygen consumption reached their own initial sea-level pattern. The observation suggests that central mechanisms are involved in bringing about a fall in body temperature during altitude acclimatization.

Key words: mean body temperature metabolism acclimatization to altitude

INTRODUCTION

Thermoregulatory adjustments during acclimatization to altitude are not studied extensively in man. It is reported that hypoxia decreases the ability of mice, dogs and men to control the body temperature during exposure to cold (11). It is shown by animal experiments that hypoxia reduces body temperature (1,2,14,17). A fall in rectal temperature preceded by a reduction in the oxygen consumption in guinea pigs and kittens is shown by Hill who proposed the hypothesis that hypoxia eliminates extra oxygen consumption required at low abmbient temperatures to maintain the body temperature (9). In man, Kottke *et al.* (11), and Wezler and Frank (20) found a fall in body temperature under hypoxia, but Chiodi did not observe a decreased body temperature even at an altutude of 3,515 m (3).

There are many conflicting and controversial reports on the effect of altitude acclimatization on the basal metabolism in man. Many have shown that basal oxygen consumption increases on induction to altitude (6, 7, 10, 19) whereas others have shown that it does not change at all (3, 4). Nair *et al.* have observed an initial elevation of basal metabolic rate followed by a depression on comparison with the basal sea-level values (15). A number of factors such as variation in the degree of hypoxia, duration of stay, the environmental temperature and the type of diet may be responsible for this.

The role of metabolic variation as a probable cause for the changes in body temperature during exposure to altitude is not known well. Besides, very little information regarding the changes in the skin temperature during acclimatization to altitude, is available. Hence, the present study is undertaken to see the progressive changes in the body temperature and the correlation, if any, with the basal oxygen consumption during an altitude exposure of 25 days.

MATERIALS AND METHODS

Twelve healthy young men of the same ethnic group drawn from the plains between 22-28 years of age participated in this study. Their oral temperature (T_{or}) and skin temperature (T_s) on eight sites (forehead, chest, upper arm, thigh, calf, index finger, foot and toe) were recorded using YSI telethermometer (model 46 TUC) with appropriate probes. The probes (No. 409) were held in position by adhesive tapes for recording the skin temperatures. The oral temperature probe (No. 408) was kept inside the mouth near the rear molar teeth. The measurements were taken in the forenoon (0900 to 1000 hrs) after an hour of a light breakfast. The subjects were allowed to relax in a thermoneutral room (25°-28°C) with ordinary cotton clothing for a period of one hour, before the measurements. The necessary precautions for recording body temperature were strictly adhered to.

The basal oxygen consumption was estimated after an overnight fast for 14 hours, while the subjects were in bed in a comfortable thermoneutral room. The subjects were made to breathe through a low-resistance breathing valve from a Cowan Parkinson dry gas meter and the volumes were noted ater a five-minute period of stabilization. The mixed expired air samples were passed through an infrared carbon dioxide analyzer (Beckman) and a paramagnetic oxygen analyzer (Servomax Controls Ltd.) for determining oxygen and carbon dioxide. The temperature of the gas sample was also noted. From these readings the basal oxygen consumption was calculated.

The initial readings were taken at Delhi and then the subjects were flown to an altitude of 3,500 m and the body temperature measurements were taken in a similar manner after 24 hours of their arrival at altitude and thereafter at 4 day intervals for a period of 25 days. The basal oxygen consumption was estimated at weekly intervals only. Then the subjects were flown back and the temperature recordings were repeated at four day intervals for a period of seventeen days and the oxygen consumption was recorded after a week of sojourn. From the skin temperature readings, the mean weighted skin temperature($\bar{T}_s$) was computed as per the method of Mezess and Larsen(13) and Elsner *et al.*(5). The mean body temperature ($\bar{T}_b$) was calculated from $\bar{T}_s$ and $\bar{T}_{or}$ as per the equation —

$$\bar{T}_b = 0.33\ \bar{T}_s + 0.67\ \bar{T}_{or}$$

RESULTS

Fig 1 shows the changes in oral temperature (T_{or}), mean weighted skin temperature ($\bar{T}_s$) and the mean body temperature ($\bar{T}_b$) of the subjects during the period of study. The mean

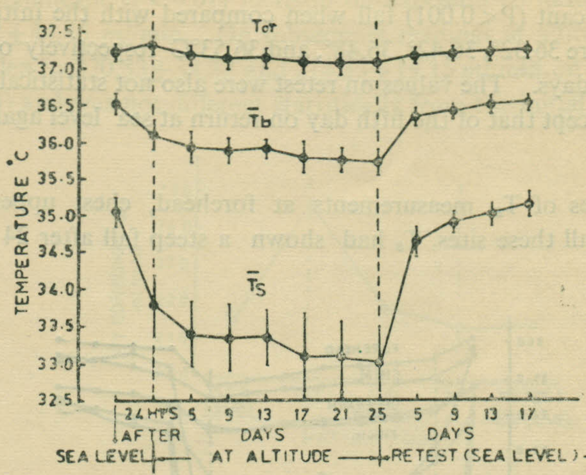

Fig. 1: Oral temperature ($\bar{T}_{or}$) Mean body temperature ($\bar{T}_b$) and Mean weighted skin temperature ($\bar{T}_s$) changes during the period of study.

T_{or} of the subjects initially was 37.21°C. After 24 hours stay at altitude the T_{or} exhibited an increase of 0.9°C. Then there was a steady and continuous fall in the T_{or} on the subsequent readings at altitude and the values were 37.17°, 37.14°, 37.13°, 37.08°, 37.05° and 37.05°C respectively at every four day interval. This fall was highly significant ($P < 0.001$) when compared with the first day value (24 hours after) at altitude. But on comparison with the initial sea-level value the T_{or} showed a highly significant ($P < 0.001$) fall only from the seventeenth day onwards at altitude. The fall was just significant ($P < 0.05$) with that of the sea-level readings by the thirteenth day, whereas the fifth and ninth day, values were not statistically different. The mean value of T_{or} on the fifth day of the subjects return to sea level was 37.14°C which became 37.18°, 37.21° and 37.22°C every four days thereafter respectively. None of these values were statistically different as compared to the initial sea-level readings.

The initial sea-level mean value of $\bar{T}_s$ was 35.06°C which became 33.80°C after 24 hours stay at altitude. This fall was highly significant ($P < 0.001$). The values of $\bar{T}_s$ at the subsequent four day intervals at altitude were 33.42°, 33.35°, 33.37°, 33.11°, 33.11° and 33.02°C respectively. All these values maintained a highly significant difference ($P < 0.001$) with those of the initial sea-level readings. On return to sea level, $\bar{T}_s$ showed a rise, the values being 34.65°, 34.87°, 35.00° and 35.15°C on fifth, ninth, thirteenth and seventeenth days respectively. These values were not satistically different on comparison with the initial sea-level readings, except that of the fifth day which still maintained a significant difference ($P < 0.001$).

The mean initial value of $\bar{T}_b$ at sea level was 36.51°C which has fallen to 36.09°C after 24 hours stay at altitude, this fall being statistically significant ($P<0.001$). On further stay at altitude, there was gradual and continuous fall in $\bar{T}_b$, the values being 35.93°, 35.89°, 35.89°, 35.77°, 35.74° and 35.73°C at every four day intervals thereafter respectively. All these values exhibited highly significant ($P<0.001$) fall when compared with the initial sea-level readings. The values on retest were 36.32°, 36.42°, 36.48°, and 36.53°C respectively on the fifth, ninth, thirteenth and seventeenth days. The values on retest were also not statistically different from the initial sea-level data except that of the fifth day on return at sea level again.

The mean values of T_s measurements at forehead, chest upper arm and thigh are showi in Fig. 2. At all these sites, T_s had shown a steep fall after 24 hours stay at altitude

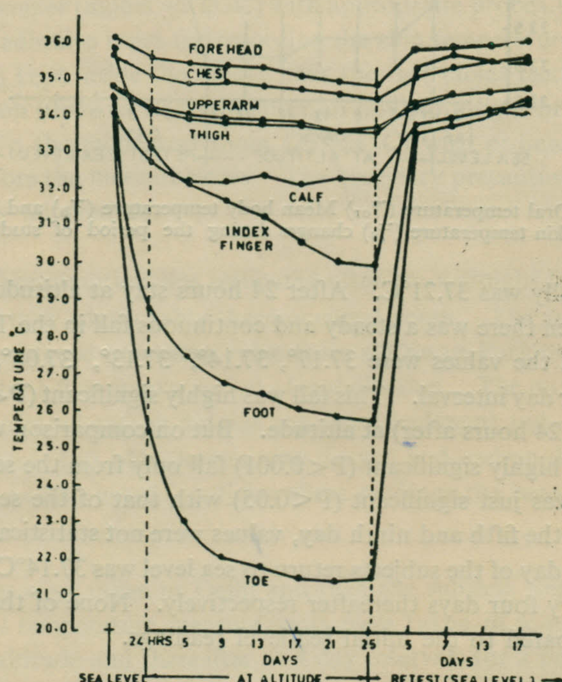

Fig. 2: Changes in the skin temperatures at various sites during the period of study.

as compared to that of the initial sea-level readings. On further stay at altitude, $\bar{T}_s$ showed a marginal decrease and on return the values had reached very near to the initial sea-level value on the fifth day itself and showed a further marginal increase on subsequent measurements. These values had reached their basal level by the seventeenth day of return at Delhi. The fall recorded in the T_s measurements on calf, index finger, foot and toe (Fig. 2) is much more as compared to the other sites. However, the pattern of the fall in the T_s was almost identical in all the sites.

The mean values of the basal oxygen consumption at Delhi was 215.33±17.91 *ml*/min. This exhibited a significant (P<0.01) increase on exposure to altitude by the first week, the value being 246.92±44.45 *ml*/min. On subsequent readings at altitude, the basal oxygen consumption had fallen to 220.33±34.32 and 214.33±19.15 *ml*/min on the second and third week respectively (Fig. 3) and was not different statistically from the initial sea-level value. On retest

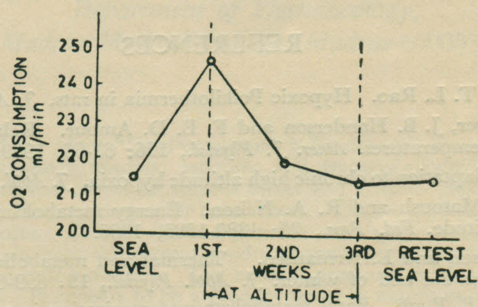

Fig. 3: Changes in basal oxygen consumption during the period of study.

the basal oxygen consumption became 215.50±16.17 *ml*/min and there exists no statistical difference with initial sea-level readings.

DISCUSSION

Significant changes in the T_{or} were not seen 24 hours after the arrival of the subjects at altitude, showing thereby that acute hypoxia of this altitude is insufficient to evoke an immediate effect on the body temperature. However, even though statistically not significant, there is a trend to record an increased T_{or} after 24 hours stay at altitude. This is in conformity with the previous observations (8,16). The observers also showed a corresponding increase in basal metabolic rate in their subjects during this period (8).

In the present observations, there is a significant elevation in the basal oxygen consumption during first week of stay at altitude. This increase is in conformity with the previous observations (6,7,10,19). This elevation in the basal metabolism can be attributed to an increase in the levels of T_3 and T_4 during the first week of stay at altitude (18). After the initial rise the basal oxygen consumption shows a fall to the sea level value by the second week, which is the case with the observation in T_3 and T_4 levels also (18).

At any rate, the significant response in the body temperature is a gradual and steady fall throughout the period of stay at altitude. The exact mechanism for this fall in body temperature is still uncertain. The significant fall in the skin temperatures at altitude clearly indicates the mechanism of peripheral vaso-constriction as an effect of hypoxia. This vaso-constriction of the cutaneous vessels is due to sympathetic overactivity (12) and it helps to redistribute the blood from the periphery to the vital organs which is a well established feature of altitude acclimatization (21). However, it is important to note that the fall in the extremity temperature is much more marked than the other cutaneous areas and this is one of the reasons for increased chances of production of cold injuries at altitude.

ACKNOWLEDGEMENTS

The authors are thankful to Messers. S.S. Verma and Swapan Kumar Das for statistical analysis of the data and to the subjects for full cooperation during the course of the study.

REFERENCES

1. Bhatia, B., S. George and T. L. Rao. Hypoxic Poikilothermia in rats. *J. Appl. Physiol.,* **27**: 583-586, 1969.
2. Blood, F. R., R. M. Grover, J. B. Handerson and F. E. D. Amour. Relationship between hypoxia, oxygen consumption and body temperatures. *Amer. J. Physiol.,* **156**: 62-66, 1969. ..
3. Chiodi, H. Respiratory adaptation to chronic high altitude hypoxia. *J. Appl. Physiol.,* **10**: 81-87, 1957.
4. Consolazio, C.F., L. O. Matoush and R. A. Nelson. Energy metabolism in maximum and submaximum performance at high altitude. *Fed. Proc.,* **25**: 1380-1385, 1966.
5. Elsner, R.W., K.L.Andersen and L.Hermansen. Thermal and metabolic responses of arctic Indians to moderate cold exposure at the end of winter. *J. Appl. Physiol.,* **15**: 659-661, 1960.
6. Gill, M. B. and L. G. C. E. Pugh. Basal metabolism and respiration in men living at 5,800 m (19,000 ft.). *J. Appl. Physiol.,* **19**: 949-954, 1964.
7. Grover, R. F. Basal oxygen uptake of man at high altitude. *J. Appl. Physiol.,* **18**: 909-912, 1963.
8. Hannon, J.P. and D.M. Sudman. Basal metabolic and cardiovascular function of women during altitude acclimatization. *J. Appl.Physiol.,* **34**: 471-477, 1973.
9. Hill, J.R. The oxygen consumption of new born and adult mammals - Its dependence on the environmental temperature. *J. Physiol. (London).,* **149**: 346-373, 1959.
10. Kellogg, R. H., N. Pace, E. R. Archibald and B. E. Vaughan. Respiratory response to inspired CO_2 during acclimatization to an altitude of 12,470 feet. *J. Appl. Physiol.,* **11**: 65-71, 1957.
11. Kottke, F. J., J. S. Phalen, C. B. Taylor, M. B. Visscherr and G. T. Evans. Effect of hypoxia upon temperature regulation of mice, dogs and man. *Amer. J. Physiol.,* **153**: 10-15, 1948.
12. Malhotra, M. S. and Lazar Mathew. Effect of prolonged stay at altitude (4,000 m) on autonomic balance. *Aerospace Med.,* **45**: 869-872, 1974.
13. Mazess, R. B. and R. Larsen. Responses of Andean highlanders to night cold. *Int. J. Biometeor.,* **16**: 181-192, 1972.
14. Moore, R.E. Oxygen consumption and body temperature in newborn kittens subjected to hypoxia and re-oxygenation. *J. Physiol. (London).,* **149**: 500-518, 1959.
15. Nair, C.S., M.S. Malhotra and P. M. Gopinath. Effect of altitude and cold acclimatization on the basal metabolism in man. *Aerospace Med.,* **42**: 1056-1059, 1971.
16. Nair, C. S. and S. George. The effect of altitude and cold on body temperature during acclimatization of man at 3,300 m. *Int. J. Biometeor.,* **16**: 79-84, 1972.
17. Reeves, J. T., E. G. Grover and R. F. Grover. Pulmonary circulation and oxygen transport in lambs at high altitude. *J. Appl. Physiol.,* **18**: 560-566. 1963.
18. Srivastava, M. C., M. S. Malhotra, G. L. Dua, R. C. Sawhney. G. K. Rastogi, K. Sridharan and Inder Singh. Hypothalamo-Pituitary-Thyroid response at high altitude. *Clinical Endocrinology,* 1976 (In Press).
19. Surks, M. I., H. J. Backwitt and C. A. Chidsey. Changes in plasma thyroxine concentration, catecholamine excretion and basal oxygen consumption in man during acute exposure to high altitude. *J. Clin. Endocrinol. Metab.,* **27**: 789-799, 1967.
20. Wezler, K. and E. Frank. Chemische wermergegulation gegen Kalte and Hitze in Sauerstoffmangel. *Pflüger's Arch. Ge's Physiol.,* **250**: 439-469, 1948.
21. Wood, J. E. and S. B. Roy. The relationship of peripheral vasomotor responses to high altitude pulmonary oedema in man. *Amer. J. Med. Sciences.* **259**: 56-65, 1970.